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LIFE-HISTORY STUDIES OF CIRPHIS UNIPUNCTA, THE TRUE ARMY WORM

By JOHN J. DAVIS and A. F. SATTERTHWAIT,
Entomological Assistants, Cereal and Forage Insect Investigations, Bureau of Entomology

INTRODUCTION

For an insect so commonly injurious and widely known as the army worm (*Heliophila*) *Cirphis unipuncta* Haworth, comparatively little concerning its life economy is recorded, and the detailed experiments herein reported represent phases of the more exact studies begun by this branch of the Bureau of Entomology.

Late in July, 1914, the army worm appeared in very destructive numbers in Huron and Sanilac Counties, Mich., and from the progeny of larvæ collected in that locality eggs and larvæ were obtained with which a series of molting and feeding experiments was started at La Fayette, Ind. The feeding experiments, where exact records of the amount of corn foliage eaten in each instar were kept, are especially interesting and instructive, for it will be noticed that more than 80 per cent of all the foliage eaten during the entire life of the larva was consumed during the last larval instar, which corroborates previous field observations to the effect that army worms rarely become evident and destructive until they are nearly full grown.

GENERATIONS OF THE ARMY WORM

During the past year (1915) *Cirphis unipuncta* was bred continuously throughout the season from moths collected from May 13 to 15, to determine the average number of generations annually. Moths of *C. unipuncta* were first observed at La Fayette the night of May 13 feeding on the honeydew produced by *Pulvinaria vitis* L.,[1] *Lecanium quercifex* Fitch,[1] and *Callipterus discolor* Monl. on white oak, and it is quite likely that these moths were the adults of larvæ overwintering in this latitude. Moths were placed in large breeding cages under natural outdoor conditions, and eggs were laid and the larvæ first observed on June 7.

[1] Kindly determined for the Bureau of Entomology by Prof. J. G. Sanders.

Pupæ were found in the cage on June 27 and the adult moths began to issue on July 8. The generation series was continued in another cage in which moths issued from July 8 to 10, eggs were found on July 14, larvæ as early as July 20, and the first adults on August 30. These adults, issuing between August 30 and September 8, were similarly confined, and eggs were first noticed on September 25 and larvæ on September 28. During the winter of 1915–16 they survived as partially grown larvæ and completed their growth in April, 1916. Thus, it is observed that in the latitude of La Fayette three complete generations may occur annually, and from numerous observations of 1914 and 1915 it is evident that in some seasons a partial fourth generation may be present. Likewise, the overlapping of generations may account for a partial fourth, although a complete fourth generation is seldom, if ever, produced in this latitude.

MOLTING AND FEEDING HABITS

The records of molts and of foliage eaten were made with larvæ confined in individual cages, three types of cages being used, namely, tin boxes, glass test tubes, and lantern globes (Pl. CVII, *A*). The tin boxes used for individuals 1 to 48 and 77 to 132 were of the common salve-box type, a 1-ounce size being used for the earlier stages and a 3-ounce size after the larvæ were about half grown. Individuals 49 to 76, inclusive, were reared in ordinary lantern-globe cages, with cheesecloth tops, placed on paper-padded saucers and containing corn foliage in bottles of water. Individuals 133 to 153 were reared in cotton-stoppered test tubes, which measured approximately 6 inches in length and 1 inch in diameter, smaller vials having been used for the first few instars. A single larva recently hatched was placed in each cage and fresh corn foliage given it as necessary. Frequent examinations were made to obtain as nearly as possible the exact hour of molting. Foliage uneaten was pressed, and from this the total amount eaten was computed for each larval instar, using for this purpose ordinary plotting paper squared to hundredths of an inch, by means of which a fairly accurate record of foliage eaten to thousandths of a square inch was obtained.[1]

The tin-box cages, 1 to 48 and 77 to 103, were kept indoors, and the lantern-globe cages, 49 to 76, and vial cages, 133 to 153, were kept on a latticed porch and were therefore under more nearly normal outdoor conditions. As the experiments were conducted for the most part during September and October, the nights were much cooler for the individuals on the porch, resulting in a noticeably longer life-cycle period for these than for the individuals kept indoors, where the coolness of the nights was much less evident.

[1] The authors take this occasion to acknowledge their indebtedness to Mr. D. G. Tower, of the Office of Cereal and Forage Insect Investigations, who assisted in measuring the pressed foliage and in making counts of eggs in the bodies of the moths.

For a summary of the data relative to the length of the various stages of *Cirphis unipuncta* and for the amount of foliage eaten in each instar, the reader is referred to Table I.[1] It will be noticed that the average lengths of the different stages for individuals in the lantern-globe cages and in glass vials were noticeably longer than for individuals reared in the tin boxes. This was not due to the difference in the style of cage, but can be accounted for, as mentioned above, by the fact that the lantern-globe and glass-vial cages were kept on a latticed porch, where the night temperature was much lower than in the laboratory where the tin boxes were kept. It will be noticed that the length of the egg stage is uniform in all cases, as they were kept under like conditions, and the average for 153 individuals was between approximately 5½ and 6¼ days. As will be noticed, the length of the first five larval instars did not vary greatly one

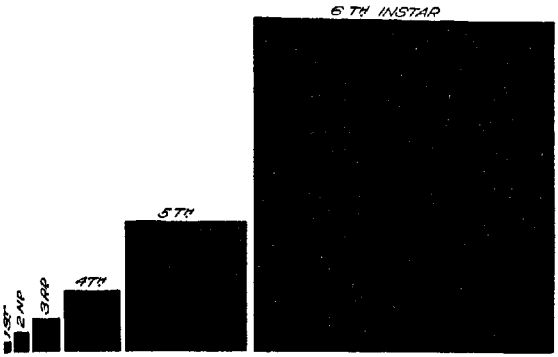


FIG. 1.—Diagram of relative amounts of foliage eaten in each larval instar by *Cirphis unipuncta*.

from the other, although the amount of foliage eaten in each of these instars was a gradual increase from nearly 0.03 of a square inch for the first instar to over 5 square inches for the fifth instar. The period for the sixth larval instar was noticeably longer than in any of the previous instars, being approximately two and one-half times as long; and the amount of foliage eaten in this instar was nearly seven times as much as in the fifth instar, and more than 80 per cent of all of the foliage eaten during the entire larval period. In other words, the total amount of foliage eaten by the larva during its entire life, an average from 108 individuals, was 41.394 square inches, and the average for the same individuals for the sixth instar alone was 34.128 square inches (see Table I and fig. 1). The remarkable voracity of the army worm during its last larval instar explains its sudden appearance in such enormous and destructive numbers only when it is nearly full grown.

[1] Owing to the size of the tables giving complete data for each individual, it is impossible to include them with this paper, but they are on file and may be obtained for reference by anyone interested.

TABLE I.—*Comparison of the molting and feeding of Cirphis unipuncta at La Fayette, Ind., from August to November, 1914*

Cage No. and date eggs were laid.	Egg stage		First instar.				Second instar.				Third instar.				Fourth instar.			
					Corn foliage eaten.				Corn foliage eaten.				Corn foliage eaten.				Corn foliage eaten.	
	Number of individuals.	Duration.	Number of individuals.	Duration.	Number of individuals.	Average area.	Number of individuals.	Duration.	Number of individuals.	Average area.	Number of individuals.	Duration.	Number of individuals.	Average area.	Number of individuals.	Duration.	Number of individuals.	Average area.
		Hours.		*Hours.*		*Sq. in.*		*Hours.*		*Sq. in.*		*Hours.*		*Sq. in.*		*Hours.*		*Sq. in.*
1 to 48 (tin boxes): Aug. 22, 9.30 p. m.	48	136.5 to 157.5	40	78.707 to 98.891	.....	.....	36	53.219 to 65.254	.....	.....	36	56.236 to 72.125	35	0.338	32	58.383 to 89.683	31	1.305
49 to 76 (lantern globes): Aug. 26, 10 p. m., to Aug. 27, 10.30 a. m.	28	127.5 to 134.75	22	88.954 to 114.216	20	0.041	21	96.614 to 104.983	21	.121	21	105.426 to 111.506	26	.346	21	68.880 to 75.928	21	1.159
77 to 103 (tin boxes): Aug. 27, 9.45 p. m.	27	140.5 to 143.33	26	94.461 to 101.221	26	.025	26	76.164 to 85.482	26	.077	26	85.502 to 96.402	26	.323	25	55.510 to 66.906	25	1.165
104 to 132 (tin boxes): Aug. 28, 6 p. m., to Aug. 29, 6 a. m.	29	135.25 to 158.50	25	83.980 to 101.920	25	.025	25	93.402 to 103.980	25	.096	24	72.229 to 81.573	24	.351	24	51.208 to 66.052	24	1.214
133 to 153 (glass vials): Aug. 29, 9.30 p. m., to Aug. 30, 10.30 a. m.	21	128 to 131	19	126.284 to 142.250	19	.031	16	94.500 to 100.578	16	.134	15	51.733 to 62.666	15	.339	14	58.393 to 70.253	14	1.101
Mean	.....	134.11 to 151.05	.....	91.366 to 107.012	.....	.0294	.....	79.452 to 88.589	.....	.103	.....	73.532 to 84.838	.....	.338	.....	63.698 to 75.109	.....	1.204
Total	153	.....	132	.....	90	.....	124	.....	88	.....	122	.....	121	.....	116	.....	115	.....

TABLE 1.—*Comparison of the molting and feeding of Cirphis unipuncta at La Fayette, Ind., from August to November, 1914*—Continued.

Cage No. and date eggs were laid.	Fifth instar.			Sixth instar.				Total corn foliage eaten.		Total length of larval stage.		Total length of pupal stage.		Total length of life cycle.	
						Corn foliage eaten.									
	Number of individuals.	Duration.	Average area of corn foliage eaten.	Number of individuals.	Duration.	Number of individuals.	Average area.	Number of individuals.	Average area.	Number of individuals.	Duration.	Number of individuals.	Duration.	Number of individuals.	Duration.
		Hours.	*Sq. in.*		*Hours.*		*Sq. in.*		*Sq. in.*		*Hours.*		*Hours.*		*Hours.*
1 to 48 (tin boxes): Aug. 22, 9.30 p. m.	29	107.784 to 116.250	4.776	24	334.104 to 344.066	29	30.262	[a] 29	36.681	24	537.6 to 561.6	24	387.780 to 393.780	29	1,084.320 to 1,089.993
49 to 76 (lantern globes): Aug. 26, 10 p. m., to Aug. 27, 10.30 a. m.	21	96.583 to 106.428	5.354	19	301.287 to 311.274	20	28.26	19	35.281	20	786.364 to 803.4	19	702.864 to 716.304	19	1,632.144 to 1,656.312
77 to 104 (tin boxes): Aug. 27, 9.45 p. m.	25	71.048 to 81.835	5.528	25	160.357 to 174.971	25	35.82	25	42.938	25	575.424 to 600.205	25	427.056 to 437.277	25	1,149.048 to 1,150.392
105 to 142 (tin boxes): Aug. 28, 6 p. m., to Aug. 29, 9 a. m.	24	63.531 to 85.382	5.794	22	179.495 to 190.716	23	47.97	23	45.450	21	574.560 to 589.102	21	429.312 to 443.272	21	1,151.112 to 1,165.752
143 to 153 (glass vials): Aug. 29, 9.30 p. m., to Aug. 30, 10.40 a. m.	13	76.725 to 80.515	5.58	13	297.675 to 301.618	13	49.982	13	48.167	13	726.264 to 742.902	13	761.928 to 768.768	13	1,632.840 to 1,636.848
Mean	.....	81.756 to 91.824	5.364	.....	203.336 to 212.261	.....	34.128	.....	41.304	.....	626.52 to 641.333	.....	512.328 to 518.976	.....	1,276.488 to 1,287.442
Total	112	.....	.....	103	.....	110	.....	108	.....	103	.....	102	.....	107	.....

[a] This record does not include foliage eaten in first two instars.

It will be noticed that the egg stage approximated 6 days, the larval stage required about 26 days, and the pupal stage 21 days for over 100 individuals and that the average length of life cycle for these was 53 days. It will also be noticed that for the cages kept indoors, which would approximate late spring, summer, or early fall conditions, the total length of the larval period averaged about 23 days; that of the pupal period about 17 days, and that of the entire life cycle approximately 47 days; while for the individuals kept on the back porch, which approximated early spring or late fall conditions, the average length of the larval period was about 31 days, the pupal period 30 days, and the total life cycle approximately 68 days. The larva has six instars, molting five times previous to pupation. However, this may vary, for among the 107 individuals reared through to the adult stage one had seven instars, molting six times.

In the outbreak in Michigan, which claimed attention in the latter part of July, 1914, oats, barley, corn, grass, alfalfa, and beets were attacked in the order mentioned. Oats and barley were backward on account of an unusual June freeze and for this reason were more succulent and attractive to the army worms. In the case of small grains, especially oats, the relative amount of injury was much greater in proportion to the amount of actual food eaten than for such crops as corn, for in the former case the grain was clipped from the stalks by the worms, leaving most of the grain uneaten and the ground whitened with the grain heads.

At the time of the outbreak mentioned above the corn was 2 feet in height. Montgomery[1] has shown that mature corn plants have a foliage area of 927.8 to 1,912.9 square inches, with an average of 1,200 square inches. Corn plants 2 feet in height would have at the most not more than one-twelfth the foliage area of a mature plant; hence, it can be said with comparative assurance that a corn plant such as was found in Michigan during the 1914 outbreak would have not more than 100 square inches of foliage. Since one larva would eat 414 square inches, it would require five larvæ to devour two corn plants. With 8,890 corn plants to an acre (2½ plants to a hill and 3½ feet each way), it would require 21,473 worms to destroy an acre of corn 2 feet in height. Although seemingly a large number of worms, this number represents only the progeny of probably not more than 40 female moths.

According to the observations of the writers, the eggs laid at night in clusters of 25 to 134 on grass or other host plant between overlapping leaves fastened together or between the leaf sheaths, often none of the eggs or only a small part of the mass being visible (Pl. CVII, *B*). They are fixed to the leaf by means of a glutinous secretion which when dry is white and flaky. The largest number of eggs laid by a single female was 254 (see Table II), and in all cases where

[1] Montgomery, E. G. Correlation studies of corn. *In* Nebr. Agr. Exp. Sta. 24th Ann. Rpt., 1910, p. 108–159, illus. 1911.

the body of the dead female was examined many more eggs in all stages of development were found in the ovaries. In some cases more than 800 developed and undeveloped eggs were contained in the body of a single female.

The newly hatched larvæ first eat the eggshells, but apparently do not eat the white substance by which the eggs were attached. Later they feed on the tissues of the corn leaf on which they are resting, destroy the parenchyma, and leave the other leaf surface as a transparent membrane (Pl. CVII, *C*). Later, they feed from the edge of the leaf, devouring all the leaf tissue.

In the first instar the larvæ, if slightly disturbed, give themselves a compound twist, "humping" the body and drawing the head and thoracic segments around, bringing the ventral surface forward, and clinging by the pseudolegs and anal claspers. If further disturbed, they drop on a silken thread, and in this twisted position resemble balls of frass, losing all semblance of the larval form. Sometimes the larvæ contort themselves with a snap or fling, without the silken attachment, which fact seemed to explain the loss of an occasional individual in the experiments.

TABLE II.—*Eggs laid by individual females of Cirphis unipuncta at La Fayette, Ind., August to September, 1914*

Cage No.	Aug. 26.	Aug. 27.	Aug. 28.	Aug. 29.	Aug. 30.	Aug. 31.	Sept. 1.	Sept. 2.	Sept. 3.	Sept. 4.	Sept. 5.	Sept. 9.	Total.	Eggs in body of dead female.	Total eggs laid and in body.
K[1]	.....	.....	.....	77	12	(2)	.....	.....	.....	.....	.....	.....	89	(1)	.....
L[1]	.....	23	5	90	20	.....	4	71	30	.....	(2)	.....	254	91	345
L[2]	.....	.....	.....	23	41	92	5	48	3	(2)	.....	.....	214	55	269
L[3]	.....	.....	.....	.....	134	39	48	(2)	.....	.....	.....	.....	221	(1)	.....
M[1]	18	28	15 34 03	43	21	(2)	.....	.....	.....	.....	.....	.....	219	62	281
M[2]	15	.....	.....	.....	.....	(2)	.....	.....	.....	.....	.....	.....	15	431	446
M[3]	.....	.....	.....	19	.....	.....	51	.....	.....	.....	.....	(2)	64	(1)	.....

[1] Abdomen of dead moth not examined. [2] Died.

The use of a silk thread by larvæ when disturbed occurred with less frequency in the second instar. After dropping, the first-instar larvæ remain inactive for a moment before attempting to crawl away; and in later instars they swing the head or fore part of the body vigorously to one side and feign death. During the fifth molt, a disturbed larva feigned death for five minutes.

During the first and second instars the larvæ walk in a looping manner, but this characteristic is lost in the third and succeeding instars.

As the larva approaches a molt, the condition is recognizable by the largeness of the body diameter as contrasted with that of the head. When within a few hours of the molt, the larva habitually anchors its anal

claspers to whatever it is resting upon, usually a rigid object rather than the foliage. In some cases—for more than 14 hours in the third instar, 21 hours in the fourth instar, and 56 hours in the fifth instar—before the molt occurs, the apparent movement of the ocelli may be observed from their normal position to a position entirely behind the mask and within the stretched integument of the first thoracic segment. Before the rupture of the integument takes place, the old mask is in the position of a muzzle in relation to the withdrawn head. The mask separates from the body integument, which splits along the median dorsal line for perhaps four segments. The larva moves its head vigorously from side to side and brushes the mask off against some object or its own body. The withdrawal of the body from the integument begins with the muscular action of the body, the larva ultimately crawling forward a distance about one-fourth or one-half its length, and after resting thus for a time if undisturbed, it will almost always turn around and eat its newly molted skin. In no instance was a mask observed to be eaten. Immediately after molting, the head and anal segments are white, the body and cast skin moist, and the head noticeably larger in diameter than the body.

One larva was observed to eat its cast skin in four to four and one-fourth minutes. Another, which required only three minutes, held the cast skin with the front pair of legs, remaining stationary and pulling the skin to it, using the second pair of legs to hold to the foliage for the first minute and utilizing them to help manipulate the partly eaten skin. Another, in the third instar, took eight and one-half minutes to eat all but a trace of its freshly cast skin. It used its front legs almost continuously and the second pair of legs about half the time in holding the skin while eating it. Another had occupied about five minutes in this process when it was accidentally interrupted.

When the mature larva has finished feeding, the alimentary tract is soon emptied and shortens up to a marked degree, the larva then preparing to spin a thin cocoon. In nature the larva burrows into the ground or among or under trash. In the cages soil was supplied to some; others had only the paper on which they were lying, others were among corn foliage, and some had nothing whatever to utilize for a cell. In those instances where soil was supplied, the larva spun an appreciable quantity of silk as lining for its cell. Where paper was cut, the effort was appreciable, but not enough silk was used to form more than a shallow cup. Where there was foliage, it was chewed up and mixed with silk, but with scant resemblance to a cocoon; where no material was furnished, the silk was not evident, although pupation and the issuance of adults seemed to be equally normal.

Just before pupation a deep pit develops in the emargination of the posterior dorsal line of the mask, and transverse ridges on the dorsal portion of abdominal segments 5, 6, and 7 show distinctly through the larval skin. These ridges, interrupted at the ends, are marked with 20

to 22 blunt teeth, which appear as transverse striæ. Also the prothoracic spiracles of the pupa are observable just dorsad of those on the larva through the mesothoracic integument of the larva as red-brown chitinized spots. Two or three minutes before the skin begins to split, the dorsum of the second segment of the thorax had changed its shape conspicuously, suggesting a scutum or scutellum extension. The skin on the fifth and following abdominal segments appears to be shriveled up and ready to drop off about 15 minutes before pupation. A red mark observed on the clypeus of the new pupa is not observable through the larval mask.

Pupation, so far as the molt of the last larval skin is concerned, was observed to take place in about a minute. The integument splits along the median dorsal line of the thorax and the pupa vigorously works itself out. The mask splits along the inner seams of the genæ, leaving a triangular piece above the clypeus, and the whole remains clinging to the cast skin after the pupa has escaped. The lining of the esophagus was cast with the mask. The compound eyes continued as dark spots on the new pupa for several minutes after the mask had split. The wing pads at time of escape of pupa from exuvium—about four minutes after the mask first split—reached 8.25 mm. back from the apex of the head. The red-brown spot on the clypeus of the pupa is slightly above the point from which the esophagus was cast. There was no apparent function for this spot. The prothoracic spiracles of the pupa are red-brown, as evidenced through the larval skin a few minutes before pupation, and those posterior lack the red color but have slightly dusky rims. About 14 minutes after the molting the wing pads reached 9.60 mm. back from the apex of the head. From other observations the color of the prothoracic spiracles of the pupa may vary to crimson and other spiracles to pinkish red or rosy with a fine line of dark red at the rim. The pupa is at first cream-colored; in about 18 minutes after issuing it is a pale salmon, and in 25 minutes it begins to get brown. After that it browns up rapidly, but one and one-fourth hours afterwards it has not become full mahogany brown. The anal spines appear to be very useful in "kicking off" the exuvium. About 15 minutes after pupation the fat body shows through the wing pads and is irregularly assembled at ends of abdominal segments. About 30 minutes after pupation the two abdominal segments next behind the wing pads are getting rosy bands, and the last three segments are almost solidly the same color. The dorsum of the abdomen is of a dark-rose color, with two or three segments on the dorsal aspect having brown, roughened, chitinized edges. About 45 minutes after molting, the abdomen behind the wing pads is nearly uniformly rosy. The fat body now appears in rings through the wing pads. About one and one-fourth hours after pupation, the rose color gradually changes through dark salmon to light red-brown. The abdomen continues light red-brown for two and one fourth hours after, but no red has begun to appear on the wing pads. Within three and

three-fourths hours the abdominal segments are nearly the normal shining red-brown.

Immediately after pupation the pupa stretches itself longitudinally almost to bursting, remains so from 12 to 15 minutes, and has been observed to contract and then extend itself again before resuming a natural appearance. On three pupæ immediately after pupation there was a transverse red-brown mark on the clypeus near its base and between the compound eyes. Each of these pupæ, while nearly white, showed a red-brown spot dorsad of the antennæ, which is the prothoracic spiracular spot.

The moth, immediately after emerging from the pupal shell, often carries a drop of clear fluid at its mouth. It then runs for a short distance. The wings require about 20 minutes to become fully expanded, with the upper surfaces folded together and hanging, and within one and a quarter hours they are in natural position flat on the back or slightly tectiform.

DESCRIPTION OF STAGES[1]

THE EGG

When first laid the eggs are perfectly smooth, shining milky white, and without any trace of sculpturing. Later the color changes through cream to flesh color, and just before hatching to a leaden cast. From a dorsal view they are apparently symmetrically spherical, but when laid in rows or masses, as is usually the case, they become compressed on two sides. Length, dorsal view, 0.542 to 0.561 mm.; width, dorsal view, 0.425 to 0.464 mm.

THE LARVA

FIRST INSTAR.—Head pale vandyke brown, shining, its posterior margin deeply emarginate. Ocelli blackish, 12 in number, 6 on each side of the head, 5 of which are arranged in a semicircular form, the lowest of the 5, however, being separated by a space so that it appears paired with the sixth, which is located near the base of antenna. Cervical shield on prothoracic segment pale dusky. When first hatched the body is whitish, later becoming tinged with green, due to chlorophyll from the foliage eaten. Entire body sparsely clothed with moderately long fine hairs, which are about as long as half the width of the body, those projecting from the head and sides of the body whitish, the dorsal hairs blackish, and the body hairs on more or less conspicuous black tubercles. The fore pair of abdominal legs are somewhat atrophied, which may account for the characteristic looping walk of the first and second instar larvæ.

Just before the first molt the head is very dark brown to almost black, and the transverse cervical shield is dusky brown. There is a clear white, shining area with several blackish dots in a row on each side extending from the anterior end of the segment to a distance about equal to the width of the cervical shield, anterior to the latter, which represents the head and ocelli of the second-instar larvæ. The ground color of the body is of a decided greenish tint, paler toward the posterior end. The body segments bear seven alternate brown-ocher and white longitudinal stripes on each side of the whitish median dorsal line; the ventral surface is white. The dorsal lines are more or less obliterated or inconspicuous on the thoracic segments. Hairs much less conspicuous than early in the instar. The thoracic legs black, the pseudo and anal legs pale dusky.

Measurements, average of two individuals, as follows: Recently hatched larva, length of body 2.11 mm., width of first thoracic segment 0.35 mm., of cervical shield

[1] All descriptions and measurements, unless otherwise noted, are from living specimens.

0.25 mm., of abdominal segments 0.28 mm., width of head 0.35 mm. Just before first molt, length of body 4.02 mm., width of prothoracic segment 0.464 mm., width of abdominal segment 0.474 mm., length of cervical shield 0.310 mm., width 0.116 mm., width of head 0.35 mm., length of cephalic hairs 0.155 mm., abdominal hairs 0.080 mm.

SECOND INSTAR (immediately after first molt).—Head very pale, shining translucent, and with a very faint tint of raw sienna; no apparent reticulate markings such as appear in later instars; tips of mouth parts brownish to black. Ocelli black and arranged as in the first instar, but more prominent and not so closely placed. Cervical shield shining, translucent, and inconspicuous, and thoracic legs faintly dusky translucent. Ground color of anterior half of body pale green, of the posterior half whitish and with stripes as in preceding instar, but the darker lines more of a yellow-ocher color. Ventral surface whitish or greenish white. Pseudo and anal legs pale translucent. The fine hairs covering the body are whitish and placed on rather conspicuous black tubercles.

Just before the second molt, the head a shining, light raw umber; mouth parts darker. The ground color of the prothoracic segment whitish, due to the head of the third-instar larva, which is plainly visible through the translucent skin. Body gradually narrowing to anal segment. Otherwise similar in markings to the recently molted second-instar larva, except that the legs are slightly darker, and the lowest brown longitudinal line is paler, tending to yellowish orange.

Measurements, average of two individuals, as follows: Recently molted larva, length of body, 3.10 mm., width of prothoracic segment 0.531 mm., width of proanal segment 0.368 mm., width of head 0.58 mm., length of longest cephalic hairs 0.348 mm.

SECOND INSTAR (just before second molt).—Length of body 6.15 mm., width of prothoracic segment 0.71 mm., abdominal segments vary in width from 0.928 mm. for the first abdominal segment to 0.74 mm. for the proanal segment; width of head 0.56 mm.

THIRD INSTAR (just before third molt).—The head shows the reticulation or brownish mottlings illustrated by Forbes.[1] Prothoracic segment transparent, the pale reddish brown reticulations and ocelli on the head of the fourth-instar larva plainly visible beneath. Body markings as in preceding description, excepting that the second dorsal brown band has broken into two brown bands and one whitish band; the third brown band has a paler more or less conspicuous line along its median; the brown band at base of legs almost obliterated; the longitudinal stripes become very faint at the anterior and less so at posterior end. The general color of the body is greenish at anterior end and cream tinted posteriorly. Ventral surface greenish white. Body hairs whitish, except those on dorsum, which are blackish. First pair of abdominal legs now fully developed. Otherwise as in previous instars.

Measurements, average of two specimens, as follows: Just before third molt, length of body 10.35 mm., width of prothoracic segment 1.26 mm., of anal segment 1.05 mm., of head 0.95 mm.

FOURTH INSTAR (just after third molt).—Head pale umber with the reticulated markings of raw sienna, as in third instar, but more prominent. General color of body Nile green, paler posteriorly. The longitudinal stripes as in preceding instar, except that lines below the line of spiracles have become entirely obliterated, the color below the spiracles being whitish green to Nile green. The dorsal lines are inconspicuous or indistinct at their extremities. Otherwise as in preceding instars.

FOURTH INSTAR (just before the fourth molt).—Head pale translucent with reticulated areas of dusky brown, darker than earlier in instar. The prothoracic segment swollen, showing head of larva of fifth instar; a light raw sienna, the reticulated mark-

[1] Forbes, S. A. A monograph of insect injuries to Indian corn. Part II. 23d Rpt. State Ent. Ill., p. 84, fig. 63 b. 1905.

ings on it plainly visible. The longitudinal stripes arranged as in preceding description, the color of the lines becoming intermixed and less distinct; the white spiracular stripe just below the line of spiracles with an interrupted ocherous line, not observed in preceding instar. The general body color is pale greenish on thoracic segments, the remaining segments gradually changing to pale yellowish brown. Spiracles black, surrounded by rather conspicuous whitish areas, those on prothoracic and proanal segments largest.

Measurements, average of two individuals, just after third molt: Length of body 10.7 mm., width of prothoracic segment 1.47 mm., of anal segment 1.28 mm., of head 1.45 mm. Just before fourth molt: Length of body 15.0 mm., width of prothorax 1.86 mm., of anal segment 1.55 mm., of head 1.47 mm.

FIFTH INSTAR (just after fourth molt).—Head as described for previous instar. Ocelli become more distant with growth of head, the posterior one of the two near base of antenna reduced to an inconspicuous spot, much resembling a seta spot. The longitudinal stripes on abdomen as in preceding instar, except that just below the line of spiracles is a narrow white line followed by another rather narrow line of reddish burnt umber, the underside of body cream-colored or with faint greenish tint; dorsal surface appearing mottled with brownish markings on pale or cream-colored background. The median slit of spiracle is more conspicuous and shows as a paler whitish area. Otherwise as in preceding instar.

FIFTH INSTAR (nearly full-grown fifth-instar larva while feeding).—The entire body from dorsal view a dirty greenish color with pink tint, the former darkest near central portion of body and along median dorsal lines and the latter more prominent at the extremities, obliterated by the dull-green coloration of the dorsum. Below the line of spiracles is a pale pinkish green longitudinal line bordered on either side by a narrow whitish line, above and below which the more or less mottled dusky-green color predominates. Spiracles as before, but of a more velvety black. Legs as before, but the pseudolegs with dusky encircling bands at extreme base visible when legs are fully extended. Otherwise as previously described.

FIFTH INSTAR (just before fifth molt).—Head and prothoracic segments of same general appearance as in preceding instar just before molting. From a dorsal view the general color is pale yellowish green to cream, the longitudinal lines being very faint with no definite outline. The broad longitudinal dark stripe just above line of spiracles contrasts strongly with the whitish or cream-colored area below the spiracles. Other markings as in preceding instar.

Measurements, average of two individuals, just after fourth molt: Length of body 13.85 mm., width of prothoracic segment 2.13 mm., of anal segment 1.64 mm., of head 2.30 mm. Nearly full grown and while feeding: Length of body 20.7 mm., width of prothoracic segment 2.59 mm., of head 2.44 mm. Just before fifth molt: Length of body 20.55 mm., width of prothoracic segment 2.90 mm., of proanal segment 2.32 mm., of head 2.38 mm.

SIXTH INSTAR (about full grown, Pl. CVII, *D*, but still feeding).—Head reticulated and mottled as before, but median suture with border of dark raw umber. Cervical shield more prominent and shining, covering almost the entire dorsum of the prothoracic segment. General color from dorsal view dirty-pale brown, paler at posterior third. The general color varies in different individuals, some being very pale while others appear very dark and in some cases even almost black. At the beginning of this instar the general color was pale with a distinct pinkish tint and the median-dorsal area was dull green, the pinkish shades predominating at the posterior extremity. A median dorsal and two conspicuous white lines laterad on dorsum of prothorax, each of the latter bordered on its inner side by a narrow dark-brown area. These white lines are extensions of longitudinal lines extending the length of the body, but are much more prominent and distinct on the prothoracic segment. The median dorsal line or stripe dark brown, its median interrupted at

intervals by narrow white dashes, these the remnants of the white median line of previous instars; laterad to this median stripe is a pale line which becomes interfused with the former along its border; below is an interrupted dark-brown stripe followed by a white stripe, and this by a rather conspicuous dark-brown stripe of the same width as last and just above line of spiracles. Below the line of spiracles is a conspicuous yellowish or cream-colored stripe with a more or less pinkish tint, contrasting with the dark-brown line above and the dusky-brown area beneath. Ventral surface of body uniformly pale, but slightly brownish or dusky, the dorsum appearing mottled and the pinkish shades rather conspicuous. Body sparsely covered with very fine hairs placed on minute black tubercles. Spiracles as in preceding instar. Legs pale dusky at joints and at tips. Pseudolegs pale and when extended a conspicuous black band is visible on outer side and extending halfway round the legs at their base.

Measurements, average of two individuals, shortly after fifth molt: Length of body 24 mm., width of prothoracic segment 3.41 mm., of head 3.48 mm. Full grown: Length of body 35 mm., width of prothorax 3.8 mm., of widest abdominal segment 6.0 mm., of anal segment 3.5 mm., of head 3.4 mm.

Individual 75, which had an extra instar—that is, seven—agreed in general markings with the description for the fifth-instar larva given above. Measurements for this individual just before sixth molt as follows: Length of body 21.2 mm., width of prothoracic segment 2.9 mm., of widest abdominal segment 4.0 mm., of proanal segment 2.4 mm., of head 2.4 mm.

The head widths are apparently good and substantial characters for distinguishing larvæ of different instars, the width varying only slightly in different individuals and never varying in any instar for the same individual. In Table III are given the average head widths for each instar, the records here given showing only those measurements actually recorded in descriptive notes, although many other corroborative measurements were made at frequent intervals.

TABLE III.—*Width of head (in millimeters) of Cirphis unipuncta at different stages of growth*

Number of individual in series.	First instar.	Second instar.	Third instar.	Fourth instar.	Fifth instar.	Sixth instar.
11	0.348					
(?)	.348					
45		0.581				
42		.581				
47		.581				
48		.542				
146		.581				
152		.581				
39			0.968			
44			.929			
9				1.432		
38				1.471		
22				1.471		
30					2.326	
36					2.284	
144					2.361	
153					2.400	
133					2.439	
61						3.484
123						3.400
Average	.348	.574	.948	1.458	2.362	3.442

THE PUPA

When fully colored of a shining mahogany brown, and comparatively smooth. In general appearance not unlike other noctuid pupæ. Dorsum of thorax with noticeable transverse wrinkles, the mesothorax with a more or less distinct smooth line along the median dorsum. Bases of first four abdominal segments on dorsum and of fifth, sixth, and seventh segments on venter rather indistinctly and sparsely punctured; the fifth, sixth, and seventh segments with a ridge near the anterior border on dorsum which reaches nearly to spiracles on each side, the posterior margin of this

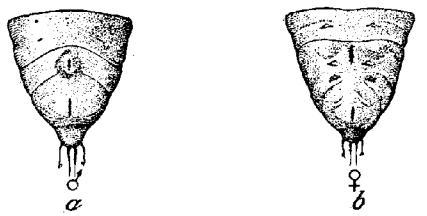


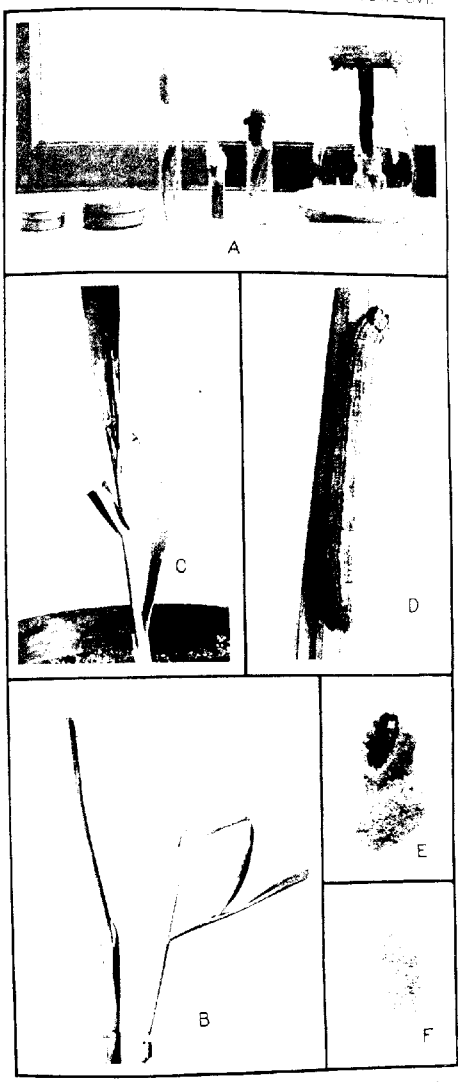
FIG. 2.—Posterior extremity of male and female pupa: *a*, Male; *b*, female.

ridge being denticulate or deeply crenulate, the teeth directed caudad and most prominent at median dorsum and gradually becoming less distinct laterally. The male and female pupæ are readily separated by a comparison of the accompanying illustrations (fig. 2).

Measurements: Length 19.3 mm.; width at tip of wings of male 6.2 mm., of female 7.0 mm. Length of the two prominent robust spines at tip of body in male 0.55 mm., in female 0.7 mm.; a more slender and more or less hooklike spine on each side of the larger one is shorter.

PLATE CVII

A, Cages for rearing *Cirphis unipuncta; B*, leaves glued together after the eggs have been deposited; *C*, characteristic leaves partly eaten by first-instar larvæ; *D*, full-grown larva; *E* and *F*, characteristic pupal cells.


A
C
D
B
E
F

INFECTION OF TIMOTHY BY PUCCINIA GRAMINIS

By E. C. STAKMAN, *Head of the Section of Plant Pathology*, and F. J. PIEMEISEL, *Research Assistant, Division of Plant Pathology and Botany, Department of Agriculture, University of Minnesota* [1]

It has been shown a number of times that *Puccinia phleipratensis* Eriks. and Henn. can infect oats (*Avena sativa*) and rye (*Secale cereale*), and it has also been shown recently that it can infect barley (*Hordeum vulgare;* (8, p. 213).[2] Inoculation of timothy (*Phleum pratense*) with *Puccinia graminis* was reported by Eriksson (2, p. 71), Johnson (3, p. 9), Mercer (6, p. 22), Stakman and Jensen (8, p. 213), and others as giving only negative results. Carleton, however (1, p. 62), succeeded in infecting *Phleum asperum* with *P. graminis avenae*.

The timothy-rust problem offers a good field for investigating the possible origin and developmental tendencies of biologic forms. The rust can infect oats, rye, barley, and a number of wild grasses; but morphologically it differs from *P. graminis*, and its ability to infect barberry (*Berberis vulgaris*) regularly is still a matter of doubt (3, p. 11). From its close similarity to *P. graminis avenae*, however, it seems reasonable to suppose that it may possibly have developed from some form of *P. graminis*. Since *P. phleipratensis* resembles *P. graminis avenae* parasitically more closely than any other biologic form of *P. graminis*, it would seem that infection of timothy with *P. graminis avenae* might be possible. For this reason the writers made a very large number of inoculations on a number of strains of timothy.

All inoculations were made on seedlings from 3 weeks to 3 months old. The leaves were first thoroughly moistened and then inoculated heavily with urediniospores of *P. graminis avenae* originally isolated from *Dactylis glomerata* and then kept on oats in the greenhouse for 14 months, having been transferred 30 times during that period. The rust had been used extensively in a large number of inoculation experiments, and the fact that it was a normal strain of *P. graminis avenae* had been well established. After inoculation the pots containing the seedlings were put in pans containing a small amount of water and were then kept covered with bell jars for 48 hours. At the end of that time they were removed and kept on an ordinary greenhouse bench. Inoculations were made with other biologic forms of *P. graminis* also; none of these, however, resulted in infection, therefore serving as checks. The "ordinary" timothy seed used was obtained from the Minnesota

[1] In cooperation with the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture.

[2] Reference is made by number to "Literature cited," p. 816.

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Seed Laboratory, and was selected from seed trade samples. The Cornell and Minnesota selections or strains were obtained from the Section of Plant Breeding, Division of Agronomy and Farm Management, Minnesota Experiment Station. A summary of the results of inoculations is given in Table I.

TABLE I.—*Results of inoculations with Puccinia graminis on Phleum pratense*

Date of inoculation.	Source of uredinio-spores.	Strain of *Phleum pratense* inoculated.	Number of leaves inoculated.	Number of leaves infected.
1915.				
Dec. 8	*P. graminis avenae* from *Avena sativa*.	Ordinary timothy.	48	0
1916.				
Jan. 25	....do....	....do....	50	5
Feb. 7	....do....	....do....	70	2
Feb. 18	....do....	....do....	234	3
Mar. 2	....do....	Cornell 1671.	248	7
Do.	....do....	Cornell 1743.	140	6
Do.	....do....	Cornell 1611.	160	4
Do.	....do....	Cornell 1715.	120	0
Do.	....do....	Cornell 1630.	96	0
Do.	....do....	Cornell 1676.	134	1
Do.	....do....	Minnesota 78	196	5
Do.	....do....	Cornell 3230.	170	1
Do.	....do....	Cornell 1687.	100	4
Do.	....do....	Cornell 1777.	94	0
Do.	....do....	Cornell 1620.	240	1
Do.	....do....	Minnesota 50	180	4
Do.	....do....	Minnesota 70	150	0
Do.	....do....	Minnesota 79	200	0
Do.	....do....	Minnesota 63 (G. Bros. 2501).	186	0
Do.				
Do.				
Do.	....do....	Minnesota 63 (G. Bros. 3801).	140	0
Mar. 23	....do....	Minnesota 77	140	0
1916.				
Mar. 23	*P. graminis avenae* from *Avena sativa*.	Minnesota 79	170	8
Mar. 3	*P. graminis tritici* from *Hordeum vulgare*.	Ordinary timothy.	28	0
Mar. 16	....do....	....do....	360	0
Mar. 30	....do....	....do....	700	0
Mar. 4	....do....	....do....	30	0
Do.	....do....	Cornell 1687.	88	0
Do.	....do....	Minnesota 63	168	0
Apr. 6	*P. graminis secalis* from *Secale cereale*.	Cornell 1715.	78	0
Do.	....do....	Cornell 1635.	60	0
Do.	....do....	Cornell 1630.	60	0
Do.	....do....	Cornell 1611	60	0
Mar. 17	*P. graminis secalis* from *Hordeum vulgare*.	Cornell 3230	72	0
Mar. 8	*P. graminis secalis* from *Elymus virginicus*.	Cornell 1676	50	0
Do.	....do....	Cornell 1687.	68	0

It will thus be seen that successful infection resulted in 14 of the 22 trials with *P. graminis avenae* and it occurred on at least 11 different selected strains which when grown in the greenhouse varied considerably in type and vigor. Unpublished results obtained by Mr. M. N. Levine, a graduate student in the University of Minnesota, corroborate the work done by the writers. Mr. Levine's inoculations were made with another strain of *P. graminis avenae*, and, although there is probably little or no difference between one strain of this rust and another, it is interesting to know that the results obtained are not due to the peculiarities of the particular rust strain used. Inoculations on oats with the spores produced on timothy resulted in the formation of typical pustules in about eight days. None of the 774 timothy leaves inoculated with *P. graminis tritici* produced pustules, and none of the 454 inoculated with *P. graminis secalis* became infected, although the writers are not convinced that these transfers are impossible.

It is quite evident both from the percentage of successful infections and from the character of the infection that timothy can not be considered a congenial host for *P. graminis avenae*. The total number of leaves inoculated was 3,270 and only 57 became infected, only 1.47 per cent. The pustules were always small, ranging in size from mere dots to pustules 0.3 mm. in diameter. On the older leaves they were often surrounded by a small dead area, indicating a certain degree of hypersensitiveness, while on younger leaves they often appeared to develop quite normally except in size. Four or five pustules sometimes developed on the same leaf, giving the appearance of fairly successful infection. The incubation period varied from 8 to 12 days. The spores were considerably smaller in size than those of *P. graminis avenae*, but they were larger than those of *P. phleipratensis*. The spores of *P. graminis avenae* are also reduced in size on barley; the character of infection is somewhat the same as that on timothy and the spores become almost identical in size. Comparative measurements of spore lengths are given in Table II.

TABLE II.—*Length of urediniospores of P. graminis avenae and P. phleipratensis*

Rust organism.	Host on which measured.	Length limits.	Mode.
		μ	μ
P. graminis avenae	*Avena sativa*	24 to 35.52	29.44
Do	*Phleum pratense*	20.16 to 32.64	25.60
Do	*Hordeum vulgare*	20.80 to 32.96	25.60
P. phleipratensis	*Phleum pratense*	16 to 28.80	21.76

Although the size of the spores is decreased on timothy, it becomes normal the first generation when the rust is transferred back to oats. The decrease in size is probably to be regarded only as a stunting due to unfavorable environment, since it has been previously shown that spores of *P. graminis* produced on an uncongenial host tend to become smaller than on a congenial host (7, p. 31). The color of the spores remains constant on oats and timothy and they can thus be distinguished very easily from spores of *P. phleipratensis*. Spores of *P. graminis avenae* are a bright cadmium-yellow in color, while those of *P. phleipratensis* are much duller, sometimes almost gray.

The fact that *P. graminis* can infect timothy raises the question as to whether *P. phleipratensis* may not have developed from some biologic form of this rust. Only speculation is possible at the present time, and a discussion of the possibilities is therefore probably useless. Nevertheless it is significant that *P. graminis avenae*, which now seems a possible source of the rust, produces urediniospores of very different shapes and sizes on the same plant and in the same pustules, thus conceivably indicating a tendency toward instability. The rust also has a wide range of hosts, in that while occurring commonly on one cereal, oats, and being

capable of infecting two others, barley and rye, it is also capable of infecting many wild grasses in this country and Europe. Until further, more extensive attempts are made to infect barberries with teliospores of *P. phleipratensis* and until the possibilities of developing experimentally a strain of *P. graminis* on timothy have been exhausted, work is more desirable than words, but the fact that *P. phleipratensis* can infect three of the cereals and a number of grasses and that timothy can be infected by *P. graminis avenae* may possibly indicate that timothy rust, as Kern (4, 5) has previously suggested, may not be so far removed from *P. graminis* as has sometimes been supposed.

SUMMARY

(1) It has been possible by means of artificial inoculations to infect various strains of timothy with *Puccinia graminis avenae*.

(2) Timothy exerted an appreciable effect on the morphology of spores of *P. graminis avenae*, reducing them considerably in size. Practically identical results were obtained by transferring the rust to barley.

(3) The rust was subnormal in vigor on timothy, the pustules always remaining small.

(4) The facts recorded in this paper are suggestive of the possible origin of *P. phleipratensis*.

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CONTROL OF THE POWDERY DRYROT OF WESTERN POTATOES CAUSED BY FUSARIUM TRICHOTHECIOIDES

By O. A. PRATT,

Assistant Pathologist, Office of Cotton and Truck Disease Investigations, Bureau of Plant Industry

INTRODUCTION

Wherever potatoes (*Solanum tuberosum*) are grown, storage-rots occur. These rots are in the majority of cases caused by wound parasites which attack the potato tubers through bruises in the skin occasioned by the handling of the potato crop in harvesting. A type of storage dryrot known as "powdery dryrot" and ascribed to the parasite *Fusarium trichothecioides* Wollenw. is apparently restricted to the arid and semiarid sections of the western part of the United States. Undoubtedly rots due to other causes also occur, but powdery dryrot is the only storage-rot causing enough damage to be of any great economic importance in the irrigated West. It would be difficult to arrive at any definite statement of the losses entailed by this disease, but it is known that they have been enormous. In several cellars visited, the writer estimated the losses caused by partial and total decay of the tubers to be from 30 to 50 per cent. Reports from farmers show that in some cases the losses have been much greater. This storage dryrot may be described as an external dryrot proceeding from bruises in the skin of the tuber. The decayed portion usually presents a wrinkled, sunken appearance, and in advanced stages may show a pinkish white growth of the fungus (Pl. CVIII, fig. 1, 2). The decayed tissue presents various shades of color from nearly black to light brown, the most characteristic color being sepia brown. Internal cavities partially filled with the mycelium and spores of the fungus are frequently found in decayed tubers (Pl. CVIII, fig. 3).

The first description of this disease was made in 1912 by Jamieson and Wollenweber,[1] who demonstrated that the rot was caused by a species of Fusarium which they called "*Fusarium trichothecioides* Wollenw." One year later Wilcox, Link, and Pool [2] described a dryrot of potato tubers in Nebraska, ascribing it to a species of Fusarium which they called "*Fusarium tuberivorum.*" This fungus has since been demonstrated by Wollen-

[1] Jamieson, Clara O., and Wollenweber, H. W. An external dry rot of potato tubers caused by Fusarium trichothecioides Wollenw. *In* Jour. Wash. Acad. Sci., v. 2, no. 6, p. 146–151, 1 fig. 1912.

[2] Wilcox, E. M., Link, G. K. K., and Pool, Venus W. A dry rot of the Irish potato tuber. Nebr. Agr. Exp. Sta. Research Bul. 1, 88 p., 15 fig., 28 pl. (1 col.). 1913. Bibliography, p. 85–88.

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weber [1] and by Carpenter [2] to be identical with *F. trichothecioides* Wollenw. Wilcox, Link, and Pool [3] found that their fungus was incapable of attacking the tubers through the eyes or lenticels and that it was incapable of attacking the growing plants. Jamieson and Wollenweber,[3] however, working with *F. trichothecioides* obtained from western potatoes, found that *F. trichothecioides* was capable of attacking the growing plant, and they also obtained infections through the unbroken skin of the tuber by rubbing the inoculum over the surface. Their results were obtained under the extremely humid conditions of the Department greenhouses at Washington, D. C.

Working with the same fungus, the writer was unable under the western field or laboratory conditions to produce infection through the unbroken skin of the potato tuber or to produce an infection in any part of a growing potato plant. His results agree in the main with those obtained by Wilcox, Link, and Pool,[4] thus further establishing the identity of *F. trichothecioides* with the so-called *F. tuberivorum*.

Preliminary work on this potato-tuber disease was begun in 1912, when the author was connected with the Agricultural Experiment Station of the University of Idaho. During the fall of 1912 and the spring of 1913 potato shippers reported heavy losses in carload lots of potatoes en route from Idaho and Utah to eastern and southern markets. Examination of infected tubers from such cars invariably revealed the presence of *F. trichothecioides*. In the fall of 1913 the writer was enabled to begin a study of storage conditions of potatoes. This study was continued up to the spring of 1916. It is safe to say that powdery dryrot can be found in every potato storage cellar in the areas covered by the author's investigations. However, when storage conditions were found to be good, losses were being reduced to a minimum.

During the whole course of the investigations, experiments leading to a further knowledge of the relationship of the fungus to the disease, as well as practical experiments leading to its control, were carried on. These experiments were conducted in part in the laboratories in Washington, D. C., and in part in the field, laboratory, and storage cellar of the Jerome Experiment Station, Jerome, Idaho. The work was further supplemented by the planting of seed plots in various places in southern Idaho. The results of these experiments, as set forth in this paper, are believed to be of fundamental scientific importance, since they throw more light on the relationship of the fungus to the disease and demonstrate a fairly successful method of control.

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[2] Carpenter, C. W. Some potato tuber-rots caused by species of Fusarium. *In* Jour. Agr. Research, v. 5, no. 5, p. 183–210, pl. A–B (col.), 14–19. 1915. Literature cited, p. 208–209.

[3] Jamieson, Clara O., and Wollenweber. Op. cit.

[4] Wilcox, E. M., Link, G. K. K., and Pool, Venus W. Op. cit.

PARASITISM OF FUSARIUM TRICHOTHECIOIDES

To determine the parasitism of *F. trichothecioides*, several attempts were made to induce infection in various parts of growing plants and in mature tubers.

1. In the fall of 1913 half-bushel lots of unbruised tubers were obtained of each of the following varieties: Burbank, Idaho Rural, Early Rose, Peoples, Improved Peachblow, Netted Gem, and Pearl. All of the tubers selected were free from any external evidence of disease and were disinfected by dipping in a solution of formaldehyde (1:240). Each tuber in one half-bushel lot of each variety was bruised with a sterile knife and the bruised surface dipped in a suspension of the spores of the fungus. Each tuber in another half-bushel lot of each variety was first carefully examined to make sure that its skin was wholly sound and was then dipped in a suspension of the spores of the fungus. Checks of the same quantity of tubers of each variety were prepared in the same manner, except that the tubers, whether sound or bruised, were dipped in sterile water. Each lot was then placed in a sterilized canvas sack. To insure a high degree of humidity each sack was sprayed with sterile water. The sacks were then stored in one corner of the cellar and covered with canvas. The tubers were not examined until the following May, or about seven months after having been placed in storage. At the time of examination all tubers had sprouted, showing that temperature conditions, at least during the latter part of the storage period, had been ideal for the development of the rot. Every inoculated, bruised tuber showed infection, each bruised, inoculated tuber being from one-eighth to three-fourths decayed. None of the inoculated sound tubers showed any infection. In the checks there was a slight amount of decay in many of the bruised tubers, though they had not been inoculated; but all of the sound tubers of the checks remained sound throughout the storage period.

2. In the fall of 1914 further attempts were made to infect potato tubers with *F. trichothecioides* through the unbroken skin. The following varieties were employed: Improved Peachblow, Idaho Rural, Netted Gem, Peoples, and Pearl. Fifty sound tubers of each variety were first disinfected in a formaldehyde solution (1:240), dried, and then dipped in a spore suspension of the fungus. Fifty tubers of each variety were disinfected in the same manner, bruised with a sterile knife, and dipped in a suspension of the spores of the fungus. Each lot of tubers was then placed in a disinfected canvas sack. The potatoes were first stored in the laboratory culture room, where the temperature was very favorable to the development of the decay. A high humidity was maintained in the culture room by spraying the walls with sterile water. After a month the potatoes were removed from the culture room to the potato storage cellar, where they remained until spring. An examination of

the potatoes was made in April, 1915. None of the unbruised tubers showed any signs of infection, but infection was present in each of the bruised tubers.

3. In 1914, attempts to artificially infect growing potato plants with *F. trichothecioides* were made as follows:

a. One hundred apparently healthy Idaho Rural plants were selected, and the stem of each was punctured at the crown with a needle inoculated with the spores of the fungus. As a check, twenty-five apparently healthy plants of the same variety were selected and their stems punctured at the crown with a sterile needle.

b. One hundred apparently healthy Idaho Rural plants were selected. The soil was removed to expose one tuber under each plant. One tuber under each plant was punctured with a needle inoculated with the spores of the fungus. As a check, twenty-five apparently healthy plants of the same variety were selected and the soil removed to expose one tuber under each plant, which was then punctured with a sterile needle.

c. One hundred apparently healthy Idaho Rural plants were selected and the soil removed to expose one tuber under each plant. The stolon of one tuber under each plant was then punctured with a needle inoculated with the spores of the fungus. As a check, twenty-five apparently healthy plants of the same variety were selected and the soil removed to expose one tuber under each plant. One tuber stolon under each plant was then punctured with a sterile needle.

An examination was made one month later. No evidence of infection could be found in the proximity of the punctures in the stems, the tubers, or the tuber stolons. The punctures made were so large that they could be seen easily in each case, but apparently they had healed over. The checks presented the same appearance.

As the foregoing inoculations of growing plants had been made rather late in the season (August 21), it was thought that the failure to develop any infection might have been due to the late date on which the inoculations were made. Therefore the attempts were repeated in 1915 as follows:

1. Fifty Netted Gem tubers which had been inoculated with *F. trichothecioides* were kept for several days in moist chambers at temperatures favorable for the development of the fungus. On June 4, when the decay was well advanced, the fifty tubers were planted in a Station plot in an attempt to infect the growing plants through the seed pieces. A similar number of hills of the Netted Gem variety were planted with disease-free seed pieces as a check. The plants were examined from time to time during the season, cultures being made whenever any evidence of disease appeared, but *F. trichothecioides* was never obtained. The plot was dug on September 15, when all stems and tubers were examined for evidence of disease. There was no evidence of decay in the harvested tubers, and the stems of the plants were usually white and clean. Six

plants out of the fifty which resulted from the planting of the inoculated seed pieces showed vascular infection, but *F. trichothecioides* could not be recovered.

2. Twenty-five Idaho Rural tubers, first disinfected by dipping in formaldehyde, were placed in moist chambers and allowed to develop sprouts. On July 10, when the sprouts were from one-eighth to one-half inch long, they were sprayed with a spore suspension of the fungus. As a check, twenty-five Idaho Rural tubers were treated in the same manner, but the sprouts were sprayed with sterile water. After a little more than a month each sprout was carefully examined. No evidence of infection was found either in the sprouts sprayed with the spore suspension or in the checks.

3. On July 11 further attempts to infect growing potato plants were made as follows:

a. Ten apparently healthy Idaho Rural plants were selected. The soil was removed to expose as many of the tubers as possible without disturbing their position. In all, twenty-five tubers were uncovered and punctured with a needle inoculated with the spores of the fungus, after which the soil was replaced. As a check, a similar number of plants of the same variety were selected and twenty-five tubers punctured with a sterile needle. This experiment was duplicated with Netted Gems.

b. Ten apparently healthy Idaho Rural plants were selected. The soil was removed to expose as many of the tubers as possible without disturbing their position. Twenty-five tubers thus uncovered were sprayed with a suspension of the spores of the fungus, after which the soil was replaced. To prevent the rapid drying off of the sprayed tubers, the soil when replaced was moistened. As a check, ten other apparently healthy Idaho Rural plants were selected and twenty-five tubers sprayed with sterile water. The soil was moistened upon being replaced. This experiment was duplicated with Netted Gems.

c. Ten apparently healthy Idaho Rural plants were selected. The soil was removed to expose as many of the tubers with their stolons as possible without disturbing their position. The stolons of twenty-five tubers thus uncovered were then punctured with a needle inoculated with the spores of the fungus, after which the soil was replaced, care being exercised to place moist soil next to the inoculations. As a check, ten other plants of the same variety were selected and twenty-five tuber stolons punctured with a sterile needle, after which the soil was replaced. This experiment was duplicated with Netted Gems.

d. Ten apparently healthy Idaho Rural plants were selected and the stem of each plant punctured at the crown with a needle inoculated with the spores of the fungus. As a check the stems of ten plants were punctured with a sterile needle. This experiment was duplicated with Netted Gems.

e. The leaves of ten apparently healthy Idaho Rural plants were sprayed with a spore suspension of the fungus. As a check, the leaves of ten apparently healthy plants were sprayed with sterile water. This experiment was duplicated with Netted Gems.

In the fall a careful examination was made of each plant and tuber. Not the slightest trace of infection that could be ascribed to *F. trichothecioides* could be found, though cultures were made from suspicious-looking stem lesions and tuber discolorations. The punctures in the tubers and stolons had healed over, leaving only the slightest scars as evidence. The punctures in the stems could be found by very careful scrutiny, but were entirely healed over. There was neither internal nor external evidence of disease in the neighborhood of the punctures, whether in stems, tubers, or tuber stolons. No disease appeared in the foliage or stems as a result of spraying with the spore suspension.

The results of the attempts to induce infection in growing potato plants were such as might have been expected after several years' search in commercial fields for evidence of disease which could be attributed to this organism. Several hundred cultures have been made from diseased parts of growing potato plants. Out of these attempts, *F. trichothecioides* has been obtained but 13 times, twice from Netted Gem tubers infected with jelly-end rot and 11 times from potato stems infected with footrot. In the footrot cultures, *F. trichothecioides* was associated with other species of Fusarium, including *F. radicicola* and *F. oxysporum*, as well as other fungi. It is not likely that *F. trichothecioides* attacked the growing stem, but rather it is probable that it entered as a secondary organism after the attacks of other fungi or bacteria. The writer has shown in another paper [1] that jelly-end rot does not develop at temperatures below 10° C.; therefore *F. trichothecioides* is eliminated as one of the contributing causes of this fieldrot, since, if *F. trichothecioides* were generally present in tubers infected with jelly-end rot, such tubers when placed in storage would continue to decay at temperatures as low as 4° (see pages 825 to 827). *F. trichothecioides* has never been obtained from any other fieldrot. In commercial storage cellars, unbruised tubers have never been found infected by *F. trichothecioides;* on the other hand, the majority of bruised tubers in storage show more or less decay from this cause.

EFFECT OF PLANTING SEED INFECTED BY DRYROT

Poor stands of potatoes have been observed from year to year in many potato fields in southern Idaho. In many cases it was impossible to say whether the poor stand was due to irregularity in planting or to poor seed. In some cases, however, the only explanation that could be made

[1] Pratt, O. A. A western fieldrot of the Irish potato tuber caused by Fusarium radicicola. *In* Jour. Agr. Research, v. 6, no. 9, p. 297-310, pl. 34-37. 1916.

was the known fact that seed infected with dryrot had been planted. To determine the effect on the stand of planting seed infected with dryrot, several plots of potatoes were planted as follows:

Plot 1.—Each seed piece showed at least one healthy eye, but was almost wholly decayed. The variety planted was Idaho Rural.

Plot 2.—Each seed piece showed a pocket of dryrot at least half an inch in diameter and about as deep as wide. The variety planted was Idaho Rural.

Plot 3.—This plot was planted with seed of the same character as that used in plot 1, except that the variety was Netted Gem.

Plot 4.—This plot was as nearly as possible a duplicate of plot 2, except that the variety planted was Netted Gem.

Two check plots were also planted, one of Netted Gem and one of Idaho Rurals. In each of the check plots only seed entirely free from disease was used. The plots were planted on the grounds of the experiment station at Jerome, Idaho. Table I shows the stand which resulted.

TABLE I.—*Percentage of stand of potatoes in plots infected with powdery dryrot*

Plot No.	Variety.	Percentage of stand.	
		Four weeks after planting.	Six weeks after planting.
1	Idaho Rural	72	82
2	do	98	100
3	Netted Gem	70	85
4	do	99	100
Check	do	100	100
Do	Idaho Rural	100	100

In plots 1 and 3, in which the seed planted was nearly totally decayed, the stand never exceeded 82 per cent of the Idaho Rural nor 85 per cent of the Netted Gem. The plants in these two plots were much slower in coming up than those in the check plots or in plots 2 and 4. One month after planting, all the seed in the check plots had produced plants larger and stronger than those in plots 1 and 3, but no difference was observed between the plants in the check plots and those in plots 2 and 4. Although the stand in plots 2 and 4 was not quite perfect at the end of the first month, the straggliers soon appeared, and a perfect stand resulted. The results of these experiments specifically agreed with the observations in commercial fields. It is believed that had the wet weather of the early spring continued throughout the month of June, a much smaller percentage of the seed would have produced plants. The plots were carefully watched throughout the growing season; but after the plants had thoroughly established themselves, there was little or no difference between the plants in the diseased plots and those in the

check plots. The plants in plots 1 and 3 eventually became as strong and vigorous as those in plots 2 and 4 and in the check plots. At harvest time 100 hills from each plot were dug and the tubers carefully examined for the evidence of disease. Table II shows the percentage of disease present in the tubers at harvest time.

TABLE II.—*Percentage of disease present in potato tubers at harvest time*

Plot No.	Variety.	Scab.	Rhizoctonia scab.	Vascular infection.	Powdery dryrot.
1	Idaho Rural	2	0	36	0
2	do	0	0	38	0
3	Netted Gem	0	0	32	0
4	do	0	0	33	0
Check	do	0	0	21	0
Check	Idaho Rural	0	0	59	0

It is evident from the results that dryrot infection in the seed does not in any way influence the amount of disease in the product. No dryrot appeared in any of the plots at harvest time. The percentage of vascular infection was higher in the case of one of the check plots and lower in the other than in the diseased seed plots. A large number of cultures were made from the discolored vascular tissues of the tubers from all of the plots, but the fungus *F. trichothecioides* was never once obtained.

SOURCE OF THE ORGANISM CAUSING POWDERY DRYROT

It was evident that the organism causing the decay must be present in the soil particles clinging to the surface of the tubers when harvested, but whether *F. trichothecioides* was present in the soil prior to the planting of the potatoes or was introduced with the seed was not known. It was thought that the latter might be the case. Accordingly plots of potatoes in which all the seed was entirely free from disease and had been disinfected for 1½ hours in a solution of mercuric chlorid (1:1,000) were planted on both raw desertland and lands previously in alfalfa. Check plots were also planted in which each seed piece was well infected with the rot.

At harvest time samples of potatoes from each of the plots were placed in sterilized tin boxes and put in storage at temperatures favorable for the development of the rot. Each tin box used in the experiment was first wrapped in heavy paper and sterilized for three hours in the oven at a temperature of 160° C. To secure the samples of potatoes, the sterile boxes were taken to the field and a hill or more of potatoes dug with a trowel which had first been sterilized. The tubers were then bruised with the same trowel, the box opened, and the potatoes put into the box with a little of the moist soil in which the tubers had been growing, in order to insure proper moisture conditions within the box. The box was

then closed, wrapped, and stored. Eight of these samples were obtained: Two of Netted Gem and one of Idaho Rural from desert land plots, and one of the Netted Gem and two of Idaho Rural from alfalfa-land plots. The remaining two samples were taken from the check plots which were planted on alfalfa land. One was a sample of the Netted Gem variety, and the other was an Idaho Rural. Two months after storing the samples, the boxes were opened and the tubers examined. Every tuber in each of the eight boxes showed at least slight signs of decay, and some showed deep infection pockets of dryrot.

Isolations were made from the decayed portions of the tubers and the presence of the organism determined. Not a single culture gave negative results. It is apparent, therefore, that *F. trichothecioides* is at the present time well distributed in desert soils, as well as in those previously in cultivation, and is not necessarily introduced on the seed.

RELATIONSHIP OF TEMPERATURE TO THE DEVELOPMENT OF POWDERY DRYROT

The experiments to determine the relationship of temperature to the development of powdery dryrot were carried on in the laboratories in Washington and in the cold-storage rooms of a Washington cold-storage plant. In these experiments potatoes of the following varieties were used: Idaho Rural, Netted Gem, Peoples, Pearl, Burbank, and Improved Peachblow. Three different experiments were undertaken.

1. Tubers of each of the above varieties were first washed and disinfected by fumigating with formaldehyde gas. Two methods of inoculation were employed. The first method consisted in cutting off the stem end of the tuber and dipping the cut surface into a spore suspension of *F. trichothecioides*. The second method consisted in inoculating the tubers by puncturing the skin with a needle inoculated with the spores of the fungus. In both cases the inoculated tubers were wrapped separately in sterile paper. Tubers inoculated by each of these methods were placed in the incubators and in the incubator room. Checks were prepared in the same manner except that the tubers in one case were dipped in sterile water and in the other case were punctured with a sterile needle.

2. In the second experiment sterile blocks were cut from tubers from each of the varieties named. These sterile blocks were placed in sterile culture tubes and allowed to incubate for several days in order to insure their sterility, after which they were inoculated with the fungus and placed in the incubators and in the incubator room.

3. In the third experiment half-bushel lots of each of the varieties above named were first washed and disinfected by fumigating with formaldehyde gas. Each tuber was then cut across the stem end and the cut surface dipped in a spore suspension of the fungus, after which they

were wrapped separately in sterile paper. Each half-bushel lot was then placed in a tin box which had first been sterilized. Half-bushel lots of each variety thus prepared were placed in cold storage at temperatures of 0° and 1.1° C. Half-bushel lots of each variety were prepared in the same manner and placed in the incubator room as a check. Check lots in which the tubers were treated in the same manner but not inoculated were also placed in the incubator room and in cold storage at temperatures of 0° and 1.1° C. Table III gives the results of these tuber inoculations under the different storage conditions, showing the temperatures of the incubator chambers, the incubator room, the rooms in the cold-storage plant during the period of storage, and the condition of the inoculated tubers at the end of the storage period. In Table III the incubator chambers are designated by numbers 1 to 10 and the cold-storage rooms as A and B. All of the uninoculated checks remained sound.

TABLE III.—*Results of potato-tuber inoculations under different storage conditions*

Incubator chamber No.	Temperatures during period of storage.			Condition of inoculated tubers at termination of storage period.
	Minimum.	Maximum.	Average.	
	° C.	° C.	° C.	
1	0.2	2.1	0.8	Sound.
2	4.0	7.3	4.2	Very slight decay.
3	4.2	10.2	7.6	One-third to two-thirds decayed.
4	6.3	12.5	8.9	Nearly total decay.
5	8.9	14.4	12.0	Total decay.
6	10.0	17.0	14.7	Do.
7	11.0	19.9	17.0	Do.
8	14.0	21.8	18.0	Do.
9	15.0	25.1	19.0	Do.
10	13.8	22.5	19.9	Do.
Incubator room	19.0	26.5	25.0	Do.
A	0	0	0	Sound.
B	1.1	1.1	1.1	Do.

It is evident from the results obtained that powdery dryrot will not develop at temperatures below 2° C. At temperatures ranging from 2° to 4° (35° to 40° F.) the amount of decay will be slight, especially if the storage rooms are kept fairly dry and well ventilated.

INFLUENCE OF HUMIDITY ON THE DEVELOPMENT OF POWDERY DRYROT IN STORAGE

It has often been observed in storage cellars which were comparatively dry and well ventilated that the losses from powdery dryrot were much less than in damp, poorly ventilated cellars. The writer has been in cellars where practically every bruised tuber was from one-third to nearly totally decayed. Such cellars have invariably been exceedingly damp

and poorly ventilated. He has been in other cellars where the bruised tubers showed only an incipient rot, the decay usually extending inward from the bruised surface for less than one-fourth of an inch. Such cellars have invariably been very dry and well ventilated. It is to be regretted that there has been no opportunity to obtain the percentages of atmospheric humidity most favorable to the development of the rot. However, a preliminary study of the effect of humidity on powdery dryrot development was undertaken in the spring of 1915.

In the month of April, owing to the fact that heavy rains had been falling, the storage cellar of the Jerome Experiment Station was in a comparatively damp condition, the doors having been open for a considerable portion of the time to allow workmen to enter. At the same time the cellar under the Station laboratory building was being kept in a comparatively dry condition, while the air of the laboratory itself was very dry, owing to the fact that fire was being constantly maintained in the stove. One hundred and fifty Netted Gem tubers inoculated with *F. trichothecioides* were allowed to remain for several days in moist chambers until the fungus had well established itself, after which fifty tubers were removed to the potato storage cellar; fifty of the tubers were put in the cellar of the laboratory building, while the remaining fifty tubers were exposed to the dry air of the laboratory room. After six weeks the potatoes were examined. Though the temperature had been very favorable for the development of the rot, the fifty tubers left in the dry laboratory room showed no apparent advance in the decay from the time they had been removed from the moist chambers. Those in the laboratory cellar showed but a very slight advance in the decay, while those in the storage cellar showed well-defined pockets of dryrot, each tuber being from one-eighth to one-fourth decayed. This preliminary experiment shows that the drier the atmosphere the less will be the decay in storage from this cause.

DISINFECTION OF POTATO STOCK BEFORE STORING

In order to learn whether the progress of powdery dryrot in storage could be inhibited by disinfecting the potatoes before storage, the following experiments were set up. Both bruised and sound tubers were employed. The bruised ones had been injured in the field during the process of digging. Fumigation with formaldehyde gas was the method of disinfection used. The potatoes were fumigated in an air-tight room at a temperature of about 60° F. To produce the formaldehyde fumes the following formula was employed: Formaldehyde (40 per cent), 3 pints; potassium permanganate, 23 ounces for each 1,000 cubic feet of space. The potatoes were arranged in two lots as follows:

Lot 1 in trays, each tray holding about 50 pounds of potatoes. One tray each of bruised tubers of Early Rose, Improved Peachblow, Peoples, Netted Gem, and Pearl, and three trays of bruised tubers of Idaho Rural; also a similar number of trays of sound tubers of each variety.

Lot 2 in sacks, each holding about 100 pounds. One sack each of bruised tubers of Early Rose, Improved Peachblow, Peoples, Netted Gem, and Pearl and two sacks of bruised tubers of Idaho Rural; also a similar number of sound tubers of each variety. The potatoes were fumigated for 24 hours and then placed in storage. As a check, a similar number of trays and sacks of bruised tubers of each variety and a similar number of trays and sacks of sound tubers of each variety were put in storage without fumigation. The period of storage was from November 1, 1913, to May 10, 1914. The cellar was well ventilated and comparatively dry. The temperature throughout the storage period ranged from 0° as a minimum to 7.8° C. as a maximum.

A careful examination of the potatoes at the end of the storage period revealed the fact that a slight amount of decay had taken place in all of the bruised tubers, whether fumigated or unfumigated. Cultures were made from a large number of infected tubers, and the fungus *F. trichothecioides* was obtained. No apparent difference was noted between the fumigated and the unfumigated lots, and there was no decay in any of the unbruised tubers, whether fumigated or not. The unfumigated potatoes, however, sound or bruised, presented a much better appearance than the fumigated potatoes, owing to the injuries in the form of sunken spots which appeared on most of the fumigated tubers caused by the action of the formaldehyde fumes.

In the fall of 1915, other experiments to control powdery dryrot by disinfecting prior to storage were undertaken. On September 27, Idaho Rural tubers were dug for the experiment. One-half of the tubers were bruised in the field with the digging fork. Bruised and sound tubers were sacked separately. Twenty-five sacks of bruised tubers and twenty-five sacks of sound tubers were employed in the experiments. Each sack contained about 40 pounds of potatoes. The methods of disinfection were as follows: (1) The formaldehyde dip (1 pint of 40 per cent formaldehyde to 30 gallons of water). (2) The mercuric-chlorid dip (4 ounces of mercuric chlorid to 30 gallons of water). (3) Dusting with flowers of sulphur. (4) Dusting with air-slaked lime. The formaldehyde and mercuric-chlorid solutions were made up fresh for each disinfection.

The potatoes dug were divided into five lots, each lot consisting of five sacks of bruised tubers and five sacks of sound tubers. On September 27, a few minutes after digging, one sack of bruised tubers and one sack of sound tubers were placed in storage without disinfection. One sack each of bruised and sound tubers was dipped for two hours in the formaldehyde solution and then dried and put in storage. One sack each of bruised and sound tubers was dipped for two hours in the mercuric-chlorid solution, dried, and put in storage, one sack each of bruised and sound tubers was dusted with flowers of sulphur and put

in storage, and one sack each of bruised and sound tubers was dusted with lime and put in storage. On September 28, twenty-four hours after digging, the second lot, consisting of five sacks each of bruised and sound tubers, was treated in the same manner as that of the previous day and placed in storage. On September 29, forty-eight hours after digging, the third lot, consisting of five sacks each of bruised and sound tubers, was treated in the same manner as the first and second lots and placed in storage. On September 30, seventy-two hours after digging, the fourth lot, consisting of five sacks each of bruised and sound tubers, was treated in the same manner as lots 1, 2, and 3 on previous days and placed in storage. On October 1, ninety-six hours after digging, the fifth lot, consisting of five sacks each of bruised and sound tubers, was treated in the same manner as those on the previous days and was put in storage. In each case the disinfected potatoes were stored in the sacks in which they were disinfected. In order to give the experiment a severe test all five lots were stored for about six weeks in the anteroom of the storage cellar, where temperature and moisture conditions were favorable for dryrot development, after which they were transferred to the storage cellar proper.

On April 1, 2, and 3, 1916, examination of the potatoes was made. Each tuber was carefully examined to determine the presence or absence of decay. Wherever decay occurred, typical specimens were taken to the laboratory, and the presence of *F. trichothecioides* was determined by means of artificial cultures. All of the unbruised tubers, whether disinfected or not, were still wholly sound. The bruised tubers which were not disinfected presented essentially the same appearance in all lots. Those with deep bruises were usually from one-third to totally decayed. Those with shallow bruises in some cases showed no decay, but the majority showed at least slight decay. By "deep bruises" are meant those which penetrated the tuber tissue far enough to be partly closed up and covered over when the digging instrument was withdrawn; by "shallow bruises," those which were only skin deep, or which presented a comparatively clean cut surface. The condition of the disinfected, bruised tubers at the end of the storage period is shown in Table IV.

TABLE IV.—*Condition of the disinfected, bruised potato tubers at the end of the storage period*

Time of disinfection.	Condition after disinfection with—			
	Mercuric chlorid.	Formaldehyde.	Lime.	Sulphur.
Immediately after digging.	No decay.....	No decay.....	Decay in most tubers with deep bruises. Shallow bruises healed over.	Presented the same appearance as those dusted with lime.
24 hours after digging.	.....do.....	.....do.....	Presented the same appearance as those disinfected immediately after digging.	Do.
48 hours after digging.	Very slight decay in most tubers with deep bruises. Shallow bruises healed over.	All tubers with deep bruises from one-third to one-half decayed. Tubers with shallow bruises showing slight or no decay.	.....do.....	Do.
72 hours after digging.	Well-established dryrot in all tubers with deep bruises. Shallow bruises healed over.	Presented the same appearance as those disinfected 48 hours after digging.	.....do.....	Do.
96 hours after digging.	All tubers with deep bruises from one-quarter to one-third decayed. Slight decay proceeding from shallow bruises.	A few tubers totally decayed. Balance presented the same appearance as those disinfected 48 hours after digging.	.....do.....	Do.

It is evident from the results obtained by disinfecting potato stock prior to storage that it is possible to check the disease effectively, provided the disinfecting is done within 24 hours after digging. The solution of mercuric chlorid, which was the most effective, was fairly efficient 48 hours after digging. The formaldehyde solution gave the next best results and was thoroughly effective 24 hours after digging. It was of little or no value when applied from 48 to 96 hours after digging. There was little difference to be observed between the lots dusted with lime and those dusted with sulphur. Wherever the tuber bruises were of such a character that the lime or sulphur could reach and cover the bruised

surface, no decay occurred. The lime and sulphur dust did not always reach the deeper bruises and therefore was not effective in such cases. Disinfecting potatoes with mercuric chlorid or formaldehyde prior to storage should be of value when it is necessary to store seed potatoes in a poorly ventilated or improperly cooled storage cellar. Lime and sulphur are not recommended.

SUMMARY

(1) Powdery dryrot, caused by *Fusarium trichothecioides*, is the most important storage-rot affecting potatoes in the irrigated West.

(2) *F. trichothecioides* under ordinary western field conditions does not attack any part of the growing potato plant. Potatoes in storage are attacked only through bruises.

(3) Planting badly infected seed potatoes greatly reduces the stand. A slight amount of infection in the seed piece does not cause any serious loss.

(4) The causal organism is at the present time apparently well distributed throughout western desert soils.

(5) *F. trichothecioides* does not develop at a temperature below 2° C. No loss from powdery dryrot occurs when the storage house is kept at this temperature, or lower. In a dry, well-ventilated storage house losses will be very slight at temperatures from 2° to 4° C. (35° to 40° F.).

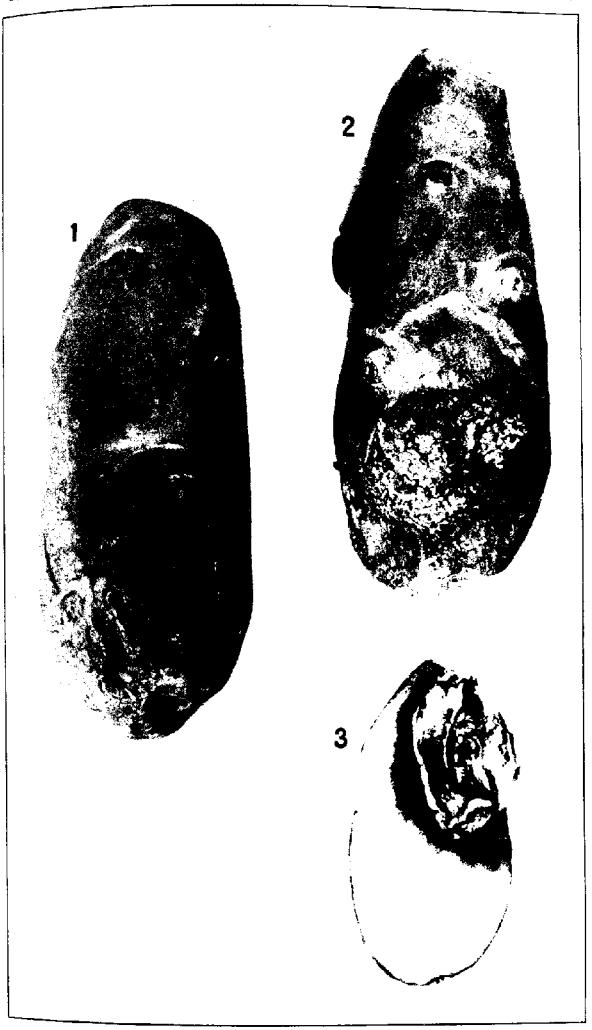
(6) Where it is necessary to store seed potatoes in a poorly ventilated or improperly cooled storage house, the disease may be effectively checked by disinfecting the stock, prior to storage, with a solution of mercuric chlorid or formaldehyde, provided the disinfecting is done immediately, or within 24 hours after digging.

PLATE CVIII

Fig. 1.—A potato tuber infected with powdery dryrot, showing the wrinkled condition of skin due to the decay of underlying tissues.

Fig. 2.—A potato tuber infected with powdery dryrot: Advanced stage. Note the presence of *Fusarium trichothecioides* on the surface of the decayed portion of the tuber.

Fig. 3.—Section through a potato tuber infected with powdery dryrot, showing the internal cavities filled with the mycelium and the spores of the fungus.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